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For

"SYSTEM AND METHOD OF FLUID LEVEL REGULATING FOR A MEDIA COATING SYSTEM"

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SYSTEM AND METHOD OF FLUID LEVEL REGULATING FOR A MEDIA COATING SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to a method and apparatus for fluid level regulation in a media coating system. More particularly, the present invention relates to a method and apparatus for sensing and regulating liquid ink and coating levels in an inkjet printing system and maintaining the satisfactory operation thereof.

Background Art

Drop-on-demand ink jet printers use thermal energy to produce a vapor bubble in an ink-filled chamber to expel a droplet. A thermal energy generator or heating element, usually a resistor, is located in the chamber on a heater chip near a discharge nozzle.. A plurality of chambers, each provided with a single heating element, are provided in the printer's print head. The print head typically comprises the heater chip and a nozzle plate having a plurality of the discharge nozzles formed therein. The print head forms part of an ink jet print cartridge that also comprises an ink-filled container.

Ink jet printers have typically suffered from two major shortcomings. First, optical density of a printed image varies greatly with the print media or substrate being printed upon. Second, ink drying time is excessive on some media types.

Interaction between the ink and print media or substrate influences the performance of the ink jet printer. Different media types behave differently with the ink and not all media types are well suited for ink jet printing. Accordingly, attempts have been made to apply a liquid coating to the media before printing that interacts with the ink to improve the quality of the resulting printed image. The ink may contain, for example, penetrants to improve dry time and binders to improve performance. These "pre-coating" liquids may contain materials that cause the ink to flocculate on the surface

of the media, improving image quality. Pre-coating liquids have previously been applied to the print media using a separate ink jet print head and by the use of a roll coating apparatus that directly contacts the print media prior to ink application. One roll coating apparatus and method of the prior art is shown and described in U.S. Patent No. 6,183,079, assigned to Lexmark International, Inc.

Thus, a primary function of the media coating device is to deliver a uniform coat of specialized fluid to the print medium prior to printing. As the media is printed on, the interaction of the fluid and the ink results in superior optical density and faster dry time. As this specialized fluid is delivered to the coating device through a supply item, it becomes necessary to detect the presence of the supply item, and detect, maintain and control the level of the fluid within the coating device for it to perform properly. In particular, when the specialized fluid in the device's reservoir is depleted, timely refill should be conducted. In doing so, overfill should be avoided, and normal printing processes should not be interrupted.

Accordingly, there is a need for an apparatus for fluid level management in a media coating system for an inkjet printer that is capable of detecting, maintaining, filling and controlling the level of the specialized fluid in the media coating system.

SUMMARY OF THE INVENTION

The present invention, in one aspect, relates to an apparatus for fluid level management in a media coating system. In one embodiment, the apparatus has a supply item for the storage of a media coating fluid and an applicator having a trough for receiving the media coating fluid from the supply item. The apparatus utilizes a fluid level detection sensor that is located within the applicator to measure whether the media coating fluid level within the trough of the applicator is either above or below a threshold position and to generate an output signal. The apparatus has a controller for receiving the output signal and controlling delivery of the media coating fluid from the supply item to the applicator.

In another aspect, the present invention relates to a fluid level detection sensor for measuring a media coating fluid level in a media coating system, wherein the media coating system has an applicator with a trough to contain the media coating fluid and the fluid level detection sensor is located within the applicator. According to one embodiment of the present invention, the fluid level detection sensor includes a first probe having a connecting end, a measuring end and a body therebetween, and a second probe having a connecting end, a measuring end and a body therebetween.

The first probe and the second probe are spaced apart from each other and the measuring end of the first probe is positioned higher than the measuring end of the second probe such that an impedance between the measuring end of the first probe and the measuring end of the second probe can be measured. The first probe and the second probe are made from conducting material such as stainless steel. Note, the first probe and the second probe can also be positioned at the same level.

Moreover, each of the measuring end of the first probe and the measuring end of the second probe has a surface contactable with the media coating fluid, and the impedance between the measuring end of the first probe and the measuring end of the second probe depends on the area of the surface of each of the measuring ends that is in contact with the media coating fluid. When at least one of the first probe and the second probe is not in contact with the media coating fluid within the trough of the applicator, the measured impedance between the measuring end of the first probe and the measuring end of the second probe is high. Conversely, when both of the first probe and the second probe are in contact with the media coating fluid within the trough of the applicator, the measured impedance between the measuring end of the first probe and the measuring end of the second probe is low.

The fluid level detection sensor also has an oscillator having an output, wherein the output is electrically coupled to the connecting end of the first probe and a detector having an input and an output. The input of the detector is electrically coupled to the

output of the oscillator and the connecting end of the first probe for receiving a signal related to the measured impedance between the measuring end of the first probe and the measuring end of the second probe and the output generates an output signal.

An embodiment of the present invention comprises a relaxation oscillator formed using a comparator. The oscillator outputs an AC signal through a resistor and a capacitor.

In a further embodiment, the detector includes a field-effect transistor having a drain, a gate and a source, wherein the source of the field-effect transistor is grounded and the gate is electrically coupled to the output of the oscillator, and a frequency discriminator having an input electrically coupled to the drain of the field-effect transistor and an output. The field-effect transistor receives an output signal having a frequency from the oscillator output and allows the output signal to pass if the amplitude of the output signal is greater than a gate threshold voltage, and the frequency discriminator receives the output signal and at the output generates a logic low if the frequency of the oscillator output is higher than a threshold frequency, or a logic high if the frequency of the oscillator output is lower than the threshold frequency, respectively. On the other hand, if the amplitude of the output signal is smaller than the threshold gate voltage, the field-effect transistor blocks the output signal. The detector may further include a capacitor that is electrically coupled between the output of the oscillator and the gate of the field-effect transistor.

The fluid level detection sensor may also have a fail-safe circuit performing a closed-loop status verification test to verify if the fluid level detection sensor is functioning properly before the applicator is filled with the media coating fluid. In one embodiment, the first probe has at least one wire, and the second probe has at least one wire. The fail-safe circuit has a transistor having a drain, a gate and a source and a capacitor electrically coupled between the drain of the transistor and a second wire of the first probe, wherein the source of the transistor is electrically coupled to a second wire of the second probe, and the gate of the transistor is adapted to receive a control signal. The

first and second wires of both probes are isolated from each other, respectively, by means such as nylon washer so that the first and second wire can contact each other through the probe body.

A further aspect of the present invention relates to a method for fluid level management in a media coating system, wherein the media coating system has an applicator with a trough to contain the media coating fluid. The method includes the steps of determining media coating fluid level within the applicator against a predetermined upper refill limit and a predetermined lower refill limit, and selectively transferring media coating fluid from a supply item to the trough of the applicator depending on the level of the media coating fluid against the predetermined upper refill limit and the predetermined lower refill limit and the status of the media coating system.

In one embodiment of the present invention the step of determining media coating fluid level includes the steps of measuring media coating fluid level within the applicator, generating a signal indicating that the fluid level is low if the media coating fluid level is lower than the predetermined upper refill limit; counting the number of pages coated since the fluid level reaches the predetermined upper refill limit; and determining if a media coating request is received.

Additionally, a further embodiment comprises the step of selectively transferring media coating fluid, when a media coating request is received, including the steps of holding a media coating operation responsive to the media coating request if the number of pages coated since the fluid level reaches the predetermined upper refill limit exceeds a first page number corresponding to the predetermined lower refill limit, and transferring media coating fluid from a supply item to the trough of the applicator.

As yet another embodiment comprises the step of selectively transferring media coating fluid, when a media coating request is received, including the steps of holding a media coating operation responsive to the media coating request if the number of pages coated since the fluid level reaches the predetermined upper refill limit is greater than the

first page number corresponding to the predetermined upper refill limit but smaller than a second page number, and transferring media coating fluid from a supply item to the trough of the applicator when the media coating operation is accomplished.

Moreover, the step of transferring media coating fluid further comprises coating fluid, when a media coating request is received, includes the steps of holding the media coating operation responsive to the media coating page request once the number of pages coated is greater than the first page number corresponding to the predetermined lower refill limit, and transferring media coating fluid from a supply item to the trough of the applicator.

Furthermore, the step of selectively transferring media coating fluid, when a media coating request is not received, includes the steps of: transferring media coating fluid from a supply item to the trough of the applicator if the number of pages coated is greater than the second page number corresponding to the predetermined high refill limit.

In another embodiment, the method further includes the steps of detecting the presence of the supply item, and detecting the presence of the media coating fluid in the supply item. If no media coating fluid is detected in the supply item, the method further includes the step of replacing the supply item with a new supply item.

In yet a further aspect, the present invention relates to a system for fluid level management in a media coating system, wherein the media coating system has an applicator with a trough to contain the media coating fluid. The system has means for determining media coating fluid level within the applicator against a predetermined upper refill limit and a predetermined lower refill limit, and means for selectively transferring media coating fluid from a supply item to the trough of the applicator depending on the level of the media coating fluid against the predetermined upper refill limit and the predetermined lower refill limit and the status of the media coating system.

In one aspect, the present invention relates to a method for fluid level management in a media coating system, wherein the media coating system has an applicator with a trough to contain the media coating fluid. The method includes the steps of determining media coating fluid level within the applicator against a predetermined upper refill limit and a predetermined lower refill limit; determining whether a media coating operation is in progress, and transferring media coating fluid from a supply item to the trough of the applicator when the level of the media coating fluid is lower than the predetermined lower refill limit and a media coating operation is in progress.

In another aspect, the present invention relates to a system for fluid level management in a media coating system, wherein the media coating system has an applicator with a trough to contain the media coating fluid. The system has means for determining media coating fluid level within the applicator against a predetermined upper refill limit and a predetermined lower refill limit, means for determining whether a media coating operation is in progress, and means for transferring media coating fluid from a supply item to the trough of the applicator when the level of the media coating fluid is lower than the predetermined lower refill limit and a media coating operation is in progress.

These and other aspects will become apparent from the following description of the various embodiments taken in conjunction with the following drawings, although variations and modifications may be effected without departing from the spirit and scope of the novel concepts of the disclosure.

BRIEF DESCRIPTION OF THE FIGURES OF THE DRAWINGS

Fig. 1 is a perspective view of a media coating apparatus according to one embodiment of the present invention.

Fig. 2 is a partial side elevation view of a media coating apparatus as shown in Fig. 1.

Fig. 3 is a lower perspective view of a fluid level detection sensor according to one embodiment of the present invention.

Fig. 4 is an upper perspective view of a fluid level detection sensor as shown in Fig. 3.

Fig. 4A is a view of an alternative embodiment of Fig. 4 in which a fluid level detection sensor utilizes a float magnet.

Fig. 5 is a block diagram for a sensor circuit utilizing a fluid level detection sensor as shown in Fig. 3.

Fig. 6 is a block diagram for an oscillator circuit that can be utilized in the sensor circuit as shown in Fig. 5.

Fig. 7 is a block diagram for a detector circuit that can be utilized in the sensor circuit as shown in Fig. 5.

Fig. 8 is a block diagram for self-test circuit according to one embodiment of the present invention.

Figs. 9A and 9B are a flow chart partially showing a process of determining the level of a fluid in a media coating system according to one embodiment of the present invention.

Figs. 10A and 10 B are a flow chart partially showing a process of filling a fluid in a media coating system according to one embodiment of the present invention.

Figs. 11A and 11B are a flow chart partially showing a process of filling a fluid in a media coating system according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Several embodiments of the invention are now described in detail. The disclosed embodiments are intended as illustrative only since numerous modifications and variations therein will be apparent to those skilled in the art. Referring to the drawings, like numbers indicate like parts throughout the views. As used in the description herein and throughout the claims that follow, the meaning of "a," "an," and "the" includes plural reference unless the context clearly dictates otherwise. Also, as used in the description

herein and throughout the claims that follow, the meaning of "in" includes "in" and "on" unless the context clearly dictates otherwise.

The present invention, in one aspect, is an ink jet printer including a coating apparatus (Fig. 1) for applying a coating liquid to a printing substrate (not shown) prior to printing. In the embodiment described here, the coating device forms one of two selectable media paths. One media path is through the applicator and a second path bypasses the applicator. The selectable paths allow media that does not require coating to avoid the applicator and also allows for the applicator to be shut down if the applicator runs out of coating fluid. The ink jet printer comprises a printing apparatus (not shown) located in a print zone within a printer housing (not shown). The printer apparatus includes an ink jet print cartridge (not shown) supported in a carrier (not shown), which, in turn, is supported on a guide rail (not shown). A drive mechanism (not shown) including a drive belt is provided for effecting reciprocating movement of the carrier and the print cartridge back and forth along the guide rail. As the print cartridge moves back and forth, it ejects ink droplets onto a printing substrate provided below it. Substrates capable of being printed upon by the printer include commercially available plain office paper, specialty papers, envelopes, transparencies, labels, card stock and the like. A more detailed disclosure of the printing apparatus, printer housing, cartridge, carrier, guide rail and drive mechanism is set out in U.S. Patent No. 6,183,079, assigned to Lexmark International, Inc. ("the '079 disclosure"), which is incorporated by reference therein.

Among other things, the present invention provides the following features:

Tracking and Control of Fluid Level With Minimal Feedback - With a simple two-state sensor that provides the indication that the fluid level is simply either above or below a threshold position, the present invention can control the fluid level to stay within a broader range. After fluid drops within an applicator of a coating apparatus, as it is being deposited on a printing substrate, an algorithm is utilized to calculate the fluid volume consumption per printed page and continually recalculate the remaining fluid volume in the reservoir. In order to prevent frequent small refill operations, the algorithm allows the fluid to drop to a minimal-acceptable level before another refill is attempted.

Logical Determination of Supply Item Status - An empty supply item is determined when a predetermined number of fill attempts fails to signify proper fluid level in the applicator. If this condition exists when the supply item is known to be present, an algorithm is utilized to determine that the supply item is indeed empty without direct measurement of the fluid level in the supply item. The algorithm can also be utilized to estimate a discreet fluid level contained in the supply item. By maintaining a consistent coat weight and knowing when a full supply item is installed, one can determine the remaining fluid level in the supply item.

Opportunistic Filling - The refill operation associated with a coating apparatus can interrupt and delay a print job. Thus, it is desirable to perform refills at times that minimize the possibility of printer delays. This is accomplished by avoiding refill operations during active printer times until the fluid level reaches an absolute minimum acceptable level. In addition, fluid is more likely added to "top off" the applicator during printer idle times. This is accomplished by having two fluid-level decision points, one low level that forces a refill under any condition and another, much higher level, that triggers a refill operation only if the printer is idle. In addition, the coating apparatus makes use of the printer power-on cycle time to refill the applicator if it is not completely full.

Fail Safe - An overfill of the reservoir of the coating fluid is considered as a failure of the system and should be avoided. Overfills may result in degraded print quality and fluid spills. It is important that if there is any failure of the system, the failure should make it appear to the system that the fluid level is full so that a refill operation is not attempted. A complete closed-loop verification of the system is performed before any refill attempt. This is accomplished by electronically shorting the sense probes through a fail safe circuit that has separate and isolated set of wires. In one embodiment, the present invention provides a four-wire configuration coupling to the two probes of the sensor.

Probe Isolation – According to the present invention, in one embodiment, the probes of a fluid level detection sensor in a coating apparatus measure the conductance between themselves to determine if fluid has reached the probes, therefore it is also possible that fluid contamination on the walls of the reservoir could appear as a conduction path, thus appearing as a full reservoir, which may prevent needed refills. This is a fail-safe mode, but if contamination does occur, it is desirable that the false conduction path dissipates in a reasonable period of time. This can be accomplished by proper isolation of the probes. In one embodiment, the geometry of the probe mountings attempts to maximize the total surface distance between the exposed metal of the sense probe and the ground probe. In addition, a large portion of this surface distance is composed of vertical surfaces, which may drain and dry more quickly.

These and other features of the present invention are described in more detail below.

Hardware Components of the Invention

The hardware associated with this invention may be described by tracing the path of a coating fluid. The present invention is initially described with reference to Figs. 1 and 2. In Figs. 1 and 2, the fluid is originally contained in a supply item, referred to as the "cartridge" **100**. In one embodiment, the cartridge **100** contains approximately 700cc of the specialized coating fluid and is blow molded out of plastics such as Polypropylene. The cartridge **100** features a threaded snout for the retention of the valve assembly **102** that releases fluid to a coating device **104**. The coating device **104** is subsequently referred to as the "applicator" **104** when it is actuated. The cartridge **100** is installed within the printer by the user and is held in position by latches that reside in the main frame assembly of the printer (not shown). An optical sensor **112**, with a spring-loaded arm, is mounted on top of the applicator **104**. It is secured to an angled surface of the applicator's **104** top housing **114**. This configuration allows for the maximum rotational travel of the optical sensor's **112** spring-loaded arm. When the user installs the cartridge **100** into the printer the spring-loaded arm is deflected and the sensor **112** is tripped, thus signifying presence of the cartridge **100** within the system.

The specialized coating fluid is delivered to the applicator **104**, through the valve assembly **102** in the cartridge **100**. As the fluid passes into the applicator **104**, it is contained in a trough that is referred to as the bottom housing **110**. The bottom housing **110** is a box made out of plastics, such as Noryl that contains 20% glass fibers. As the fluid fills the bottom housing **110**, other parts contained in the bottom housing **110** are also exposed to the coating fluid. The specialized coating fluid's primary interface is with the applicator's **104** grit roll **200** (shown as a cross section in Fig. 2). The level of the fluid relative to the grit roll **200** is important in this application. Essentially, if enough fluid is not deposited into the trough, the grit roll **200** will not be exposed to the fluid and thus will not only be prevented from coating the media, but may also damage the doctor blade **202** by tearing material from it's doctoring edge. Conversely, if too much fluid is deposited into the bottom housing **110**, print quality defects may occur as well as a leaking of the fluid outside of the applicator **104**, which may result in damage to the printer's hardware.

There are many different ways to sense the level of the fluid as it fills in the bottom housing **110**. With reference to Figs. 3 and 4, we illustrate how the inventive implementation uses a conductive method in which two probes are utilized. In one embodiment, the present invention provides a fluid level detection sensor **300**. The sensor comprises a sense probe **301** and a ground probe **302**. The fluid level of the coating fluid is determined by measuring the impedance between the sense probe **301** and the ground probe **302** in order to determine if the set of probes are in contact with the fluid. In the event that the coating fluid comes into contact with both probes, the measurement indicates that the fluid has reached the desired level.

As shown in Figs. 1-4, in another aspect, the fluid level detection sensor **300** can be utilized for measuring a media coating fluid level in a media coating system, wherein the media coating system has an applicator **104** with a trough **110** to contain the media coating fluid and the fluid level detection sensor **300** is located within the applicator **104**. According to one embodiment of the present invention, the fluid level detection sensor

300 includes a first probe or sense probe **301** having a connecting end **311**, a measuring end **313** and a body **315** therebetween, and a second probe or ground probe **302** having a connecting end **312**, a measuring end **314** and a body **316** therebetween.

The first probe **301** and the second probe **302** are spaced apart from each other and the measuring end **313** of the first probe **301** is positioned higher than the measuring end **314** of the second probe **302** such that an impedance between the measuring end **313** of the first probe **301** and the measuring end **314** of the second probe **302** can be measured. The first probe **301** and the second probe **302** are made from conducting material such as stainless steel.

Moreover, each of the measuring end **313** of the first probe **301** and the measuring end **314** of the second probe **302** has a surface contactable with the media coating fluid, and the impedance between the measuring end **313** of the first probe **301** and the measuring end **314** of the second probe **302** depends on the area of the surface of each of the measuring ends **313**, **314** that is in contact with the media coating fluid. When at least one of the first probe **301** and the second probe **302** is not in contact with the media coating fluid within the trough **110** of the applicator **104**, the measured impedance between the measuring end **313** of the first probe **301** and the measuring end **314** of the second probe **302** is high. Conversely, when both of the first probe **301** and the second probe **302** are in contact with the media coating fluid within the trough **110** of the applicator **104**, the measured impedance between the measuring end **313** of the first probe **301** and the measuring end **314** of the second probe **302** is low. The data collected from the measurements can be received in a sensor circuit for analysis, which is discussed in detail below.

Proper isolation of the sense probe **301** and the ground probe **302** is required in order to prevent the fluid from forming a conductive path in the event that the unit tips over or if fluid contained within the bottom housing **110** is splashed. The existence of such a conductive path may result in the sensor **300** registering a "false full" reading within the bottom housing **110**. This sensor failure mode may be designed to be time

dependent. In one embodiment of the present invention, the sensor's recovery time as the result of a physical jarring can be reduced to a recovery time of 5 minutes or less. Additional factors that may attribute to this conductive path phenomenon are the wettability of the surface (features such as surface tension / energy balance and surface finish), fluid viscosity, vertical features and "drip edge" features.

The sense probe **301** and the ground probe **302** can be made from materials that are corrosion resistant such as stainless steel. In one embodiment, the probes are made from stainless steel where a coating fluid that is high in salts is utilized. In such a situation it is highly desirable that the probes that are utilized be corrosion resistant in order to ensure the proper operation of the sensor. In one embodiment, the probes **301**, **302** are mounted within a glass-filled Noryl housing that has four vertical surfaces (not shown) with a combined vertical height of approximately 30mm. The coating fluid has a resistance of about 1kΩ and viscosity of about 45cP. In a momentary tipping or re-orienting event, with this embodiment, the resistance from probe to probe has a slope of 3.3kΩ per minute. This may result in a recovery time of approximately 1/3-minute, which is a reasonable constraint.

Alternatively, the fluid level detection sensor can comprise a single point level sensor. In one embodiment shown in Fig. 4A, a single point level sensor **400** includes a float **421** and a magnet **423** associated with the float **421** generating a magnetic field. The single point level sensor **400** also has a magnetic switch **425** that is positioned in the inside surface of the trough **410** substantially near or at a threshold position **430**. The float **421** floats on the surface of a media coating fluid **412**. When the coating fluid **412** is consumed, the level of the coating fluid **412** moves toward to the threshold position **430** and so does the float **421**. When the float **421** moves sufficiently close to the magnetic switch **425**, the magnetic switch **425** is activated by the magnetic field of the magnet **423**, thereby generating an output signal at outputs **427**, **429** indicating the level of the coating fluid **412** within the trough **410**. The magnetic switch **425** can be a Hall effect switch, or a reed switch. Factors that may affect this sensor design configuration

are the density and foamability (reduces density) of the coating fluid, the effective float density, and varied float stability criteria.

Additional alternative level sensors may include capacitance, thermistor, ultrasonic and optical sensors and the like.

Implementation of the Sensor Circuit

With reference to Figs. 5, 6 and 7, we will next examine the fluid level sensor circuit that may be utilized within the system. As shown in Fig. 5, the basic sensor circuit **500** of the present invention comprises an oscillator **502** and a detector **504** that are operably connected to a first **506** and a second **508** probe. The sensor **500** measures the impedance between the two metallic probes **506, 508** in order to detect the system's fluid level. When at least one of the probes **506, 508** is not in contact with the fluid the impedance between the probes is high. When both probes **506, 508** are in contact with the fluid the impedance between the probes is low.

In one embodiment, the fluid level detection sensor comprises an oscillator **502** having an output, wherein the output is electrically coupled to the connecting end of the first probe **506** and a detector **504** having an input **514** and an output **516**. The input **514** of the detector **504** is electrically coupled to the output **512** of the oscillator **502** and the connecting end of the first probe **506** for receiving a signal related to the measured impedance between the measuring end of the first probe **506** and the measuring end of the second probe **508** and the output **516** of the detector **504** generates an output signal.

Due to specific design constraints, a DC measurement of resistance is not practical because the application of a direct current causes a chemical reaction between the probes **506, 508** and the fluid that will plate one probe and erode the other. Therefore, due to the fore mentioned reason it is necessary function of the present invention that an AC measurement of resistance be executed within the system. When an AC measurement is performed, the probes **506, 508** behave as a series resistor-capacitor combination. The consequential capacitance value depends on the surface area of the

probe that is in contact with the fluid. The resulting resistive component depends on the conductivity of the fluid and the separation of the probes **506, 508**.

Fig. 6 illustrates an oscillator **600** that may be implemented within the present invention's sensor mechanism. The oscillator **600** of Fig. 6 is a relaxation oscillator that produces a square wave output. In order to remove the DC component of the output signal, the output of the oscillator **600** is coupled with a capacitor **602**. Additionally, the output component contains a resistor **604** for setting the output impedance of the oscillator **600**. It is intended that the output impedance be high so that the probes **506, 508** can easily shunt the signal to ground when in contact with the fluid.

In one embodiment, the oscillator **600** comprises a comparator **630** that is operably connected to an assortment of resistors **604**, **606**, **608**, **614**, **612**, **616** and capacitors **602, 610.** The oscillator **600** outputs an AC signal through the resistor **604**. The AC signal transmitted through the resistor **604** may embody different forms such a square wave, a sinusoidal wave, or like. In the embodiment, as shown here, a square wave is utilized.

Fig. 7 illustrates the detector **700** component of the sensor of the present invention. The detector 700 utilizes a two-step process in order to sense the output signal of the oscillator **600**. First, the detector **700** screens the transmitted signal based on amplitude. If the signal's amplitude exceeds the detector's **700** threshold, the signal is passed, if the signal's amplitude is below the detector's **700** threshold the signal is blocked. In the second step a frequency discriminator **704** is utilized in order to determine whether the signal was passed or blocked. If the signal is blocked the resultant frequency will be zero, otherwise the oscillator **600** frequency will be passed onto the frequency discriminator **704**. Subsequently, the frequency discriminator **704** produces a logic low if the frequency is above a threshold and a logic high if the frequency is below the threshold.

In one embodiment, the detector **700** includes a field-effect transistor **702**, resistors **712, 716, 720, 722, 724** and a capacitor **718**. The field-effect transistor **702** comprises a drain **708**, a gate **710** and a source **706**, wherein the source **706** of the field-effect transistor **702** is grounded and the gate **710** is electrically coupled to the output of the oscillator **600**, and a comparator **704** is electrically coupled to the drain **708**. The field-effect transistor **702** receives an output signal having a frequency from the oscillator **600** output and allows the output signal to pass if the amplitude of the output signal is greater than a gate threshold voltage, and the frequency discriminator **704** receives the output signal and at the output generates a logic low if the frequency of the oscillator **600** output is higher than a threshold frequency, or a logic high if the frequency of the oscillator **600** output is lower than the threshold frequency, respectively. On the other hand, if the amplitude of the output signal is smaller than the threshold gate **710** voltage, the field-effect transistor **702** blocks the output signal. The detector **700** may further include a capacitor **714** that is electrically coupled between the output of the oscillator **600** and the gate **710** of the field-effect transistor **702**.

Self-Test Circuitry

Fig. 8 illustrates a self-test circuit **800** that can be added to the sensor by combining a transistor **802** and capacitor **804** together to short the first probe **812** with the second probe **810**. This allows a microprocessor (not shown) to check that the first **812** and second probe **810** are electrically connected to the circuit and that the circuit is functioning. Without the self-test capability, an unconnected probe would produce a low fluid indication. In such an instance, the microprocessor would not be able to determine when to stop filling, and thus resulting in an overfill and possibly a spillage of fluid. However, with the shorting feature the integrity of the sensor can be checked before starting a fill operation, therefore avoiding an undesirable fluid spill if the sensor is not operating properly.

In one embodiment, four wires connect the sensor circuit to the first **812** and second probe **810**. Each probe has two wires, one for the sensor circuit and one for the self-test circuit **800**. The probe forms the electrical contact between the two wires

ensuring that if the self-test is successful, the wires must be connected to the probes. It is important to note that while each wire contacts the probe, they are isolated from each other by a non-conductive means such as a nylon washer. With such an arrangement, if any one of the four wires fails to make a conductive path between the probe and the circuit, the self-test will be unsuccessful.

The fail-safe circuit **800** has a transistor **802** having a drain **816**, a gate **818** and a source **814** and a capacitor **804** electrically coupled between the drain **816** of the transistor **802** and the second wire of the first probe **812**, wherein the source **814** of the transistor **802** is electrically coupled to the second wire of the second probe **810**, and the gate **818** of the transistor **802** is adapted to receive a control signal. The nylon washer assures that any electrical continuity between the first and second wires occurs through the body of the probes.

Accordingly, the self-testing feature of the present invention if properly implemented ensures that overfilling of the device will be avoided. If the sensor output is stuck in a high state, no filling will ensue, since this is a full indication. If the sensor output is low, it will be tested to see that it can detect fluid before filling is allowed.

Operation of the Present Invention

The algorithm utilized to implement the fluid level management system may best be described in three parallel processes. Each of the processes run concurrently and communicates to each other by the means of semaphores or flags. The three processes are 1) Fluid Level Determination, 2) the Main Printer Task, and 3) the Fill Task.

The Fluid Level Determination task, as shown in Figs. 9A and 9B, begins execution at block **900**. The primary function of this task is to determine the level of fluid in the applicator and if fill operations are required. The fluid level sensor is de-bounced at block **902** by looking for a predetermined number of successive identical reads. If the fluid level is determined not to be low at block **904**, the fluid low page count is cleared at block **906**. The fluid low page count is utilized to track the number of pages

coated after the sensor has transitioned to the fluid low state. Given that the volume of fluid applied to each page is known, the fluid low page count is proportional to the volume of fluid used since the fluid level sensor transitioned to the fluid low state. Since the fluid level is not low, a fill is not required and the fill-required variable is set to the not required state at block **908**. The Fluid Level Determination task then exits at block **910**.

If the fluid level is determined to be low at block **904**, block **912** determines if a print page request for the coating path has been received. If this request has not been received, the task exits at block **910**. When block **912** determines that the request has been received, the fluid low page count is incremented at block **914**. If the fluid low page count is determined not to be greater than or equal to a predetermined lower refill limit at block **916**, the fill required variable is set to the not required state at block **918** and the task exits at block **920**. If the fluid low page count is greater than the lower limit, the fluid low page count is compared against the upper refill limit at block **922**. If the fluid low page count is determined to be greater than the lower refill limit and less than the upper refill limit, fill required is set to opportunistic at block **924** and then exits at block **920**. This setting indicates that the system has used enough fluid to warrant a fill operation; however, the need to fill is not critical at this point. This fill operation should only take place during times when the printer throughput will not be affected. If the fluid low page count is determined to be greater than the upper refill limit, fill required is set to mandatory at block **926** and then exits at block **920**. This indicates that the fluid level in the applicator has fallen close to a level at which coating performance will be degraded. The need for a fill operation has now become critical and a printer operation will be interrupted in order to execute this fill operation. Once the fill-required variable is set, the task exits at block **920**.

The Main Printer Task is shown in Figs. 10A and 10B and begins execution at block **1000**. This task initiates the fill operation based upon the printer status (idle or printing) and the level of urgency assigned to the fill-required variable. Before any decisions are made about initiating a fill operation, the cartridge present sensor is checked

at block **1002**. If the cartridge is not present, the user is notified to replace the cartridge at block **1004**. The cartridge empty flag is cleared at block **1006**. This flag is cleared at this point because this flag is meant to indicate the status of the cartridge currently installed in the printer. There is not a means to directly measure that a cartridge is empty. Once a cartridge has been removed from a printer, any information determined about that cartridge is no longer valid. If an empty cartridge is installed in a printer, the cartridge will be assumed to be full until it can be determined that it is empty. The task then exits at block **1008**.

If the cartridge is detected at block **1002**, the status of the printer is checked at block **1010**. If the printer is idle (not printing), the status of the cartridge empty flag is ascertained at block **1012**. If this flag is set, indicating that the cartridge is out of fluid, all printed pages are diverted to alternate path at block **1014**. If a print page request is not received at block **1016**, the task exits at block **1018**. If the cartridge empty flag is not set at block **1012**, block **1020** determines if an opportunistic or a mandatory fill is required. If yes, the fill command is set to start at block **1022** in order to initiate the Fill task. If a fill is not required at block **1020** or if the fill command has just been set at block **1022**, the print page request is checked at block **1016**. If a print page request has been received, block **1024** checks if the printer is currently executing a fill operation. If a fill operation is under way, block **1026** checks to see if this is a mandatory fill. Upon determination that the fill is not mandatory, the fill command is set to abort at block **1028** and the print page request is processed at block **1030**. The task will then exit at block **1042**. If the printer is not filling at block **1024**, the print page request is processed and then task will then exit. When the fill is determined to be mandatory at block **1026**, the print page request is not processed. This request will be left pending until the fill process is complete.

If the printer is not idle at block **1010**, it is determined if the printer is running at block **1032**. If the printer is running, the status of the cartridge empty flag is ascertained at block **1034**. If this flag is set, indicating that the cartridge is out of fluid, all printed pages are diverted to alternate path at block **1036**. If a print page request has been

received at block **1038**, it is processed at block **1040** and the task exits at block **1042**. If the request has not been received, the task exits at block **1042**. If the cartridge empty flag is not set at block **1034**, block **1044** determines if a mandatory fill is required. If a mandatory fill is required, the task will exit at block **1042**. This allows any pages that are currently be processed to be completed and prevents any new pages from being processed. The printer will return to the idle state after the pending pages are completed and the logic described above will initiate the mandatory fill. If a mandatory fill is not required at block **1044**, the execution continues at block **1038** with checking for a print page request as previously described.

The Fill task is illustrated in Figs. 11A and 11B. This task is intended to control the fill mechanism and determine if the cartridge is empty. Upon commencement of the Fill task at block **1100**, a check for the fill command being set to start is made at block **1102**. If successful, the fill command is cleared at block **1104** and the self-test circuit is energized at block **1105**. If the self-test fails at block **1106**, the user is notified of this error and the entire printer is shutdown at block **1108**. The task is then complete and exits at block **1114**. If the self-test passes at block **1106**, the fill state is set to filling at block **1110** and the fill mechanism is energized at block **1112**. The task then exits at block **1114**.

If the fill command was not set to start at block **1102**, block **1116** checks for the fill command being set to Abort. If the abort command is found, it is cleared at block **1118** and the fill mechanism is de-energized at block **1120** and the task exits at block **1114**.

If the abort command is not found at block **1116**, the status of the fill state is determined at block **1122**. If the fill state is filling, the fluid level sensor is de-bounced at block **1124** and then the fluid level is checked at block **1126**. If the fluid level is not low, the fill mechanism is de-energized at block **1128** and the fill state is cleared at block **1130** before the task exits at block **1140**. If the fluid level is low at block **1126**, the determination is made at block **1132** if the fill mechanism has been energized for a

predetermined period. This predetermined period is set so that barring any failures, the fill mechanism will transfer sufficient fluid from the cartridge to the applicator to cause the fluid level sensor to detect the full fluid condition. If the fill mechanism has not been energized longer than the predetermined period, the fill operation is allowed to continue and the task exits at block **1140**. If the predetermined period has been exceeded, the fill mechanism is de-energized at block **1134**. Since the fill operation did not succeed, it is determined that the cartridge is empty. A message indicating this empty state is posted at block **1135** and an internal flag indicating that the currently installed cartridge is empty is set at block **1136**. Finally, the fill state is cleared at block **1138** prior the task exiting at block **1140**.

Once the Fill task has successfully transferred fluid from the cartridge to the applicator, the Fluid Level Determination task with detect that the fluid is no longer low and clear the fluid low page count and set the fill required to not required. If the Fill task is not successful, the Fill required will still be set, but the cartridge empty flag will prevent the Main Printer task from initiating another fill operation until the cartridge is removed and replaced.

Although the present invention has been described with reference to specific details of certain embodiments thereof, it is not intended that such details should be regarded as limitations upon the scope of the invention except as and to the extent that they are included in the accompanying claims.